Evaluating the Accuracy of Trawl Logbook Estimates of Groundfish Discards

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ABSTRACT

The Enhanced Data Collection Project (EDCP), administered by the Oregon Department of Fish and Wildlife, collected data on discard rates for groundfish species and bycatch rates of prohibited species. From late 1995 to early 1999 EDCP observers collected discard data from 235 fishing trips by 25 trawl vessels that voluntarily participated in the program. Besides these observer data, vessels in the program kept enhanced logbooks that recorded retained and discarded catch. These logbooks had data from 866 trips by 44 vessels, including most of the trips with observers. Provided logbook data are acceptably accurate, collecting discard data using logbooks could be a cost-effective supplement to an observer program for measuring discard rates and total discards. Comparisons of tow-by-tow logbook discards with the corresponding observer discards indicated substantial inaccuracies in the logbook information. However, when averaged across tows, trips, and vessels, the discard rates (discard/catch) from the logbooks were lower than the observer discard rates, but predictably so. Generalized linear models were used to determine the major factors contributing to variability in the discard rates. The models indicated tremendous vessel-to-vessel variability in discard rates. Principal components analysis (PCA) was applied to trip-level landings and species compositions from the entire groundfish trawl fleet to summarize the fleet-wide characteristics of fishing trips. Analyses of the PCA scores from the trips that were in the EDCP compared to the scores from all other trips indicated that the EDCP trips probably were not representative of the fleet at large.

Keywords: discards, bycatch, groundfish, logbooks, observers, trawl fishery

INTRODUCTION

In 1995 the Oregon Trawl Commission contracted with the Oregon Department of Fish and Wildlife (ODFW) to begin the Enhanced Data Collection Project (EDCP). The major goals of the project were to collect data on trip-limit induced discard rates for primary groundfish species, discard rates for other groundfish species, and bycatch rates of prohibited species (Pacific halibut and salmon). From late 1995 to early 1999 EDCP at-sea observers collected discard and bycatch data from over 200 fishing trips by trawl vessels that voluntarily participated in the program. In addition to these observer data, boats participating in the program kept enhanced logbooks in which the skippers recorded their retained and discarded catch. These enhanced logbooks have data from over 800 trips, including most of the trips with observers.

For this study the Commission contracted with Oregon State University to analyze the EDCP databases, which were provided by ODFW on CD-ROM. The analyses compare the discard rates measured by the EDCP at-sea observers with the discard rates reported by the corresponding enhanced logbooks. The overall goal was to examine the feasibility of using logbooks, in conjunction with some observer coverage, to measure discard rates and total discards for use in stock assessments and by management. The main objectives of the analyses were: (a) to evaluate the accuracy of the skippers' estimates of discarded groundfish catch; (b) to estimate average discard rates for the major groundfish species and determine the factors that contribute to variability in the discard rates; and (c) to evaluate whether the boats that volunteered to participate in the EDCP were representative of the fleet at large.

Description of the EDCP Data

The EDCP data were in three primary files. One file had tow-by-tow data collected by the observers on discards of the main groundfish species and the bycatch of halibut and salmon, data from a total of 2,172 tows from 235 fishing trips by 25 different fishing boats. A second file had trip-by-trip summary data from the observed trips on the total amounts of discards of the main groundfish species and the bycatch of halibut and salmon, and included data from the fish tickets (the official landing receipts) on the retained catches of the main groundfish species. A third file contained the skippers' tow-by-tow estimates of retained and discarded catch of the main groundfish species and the bycatch of halibut and salmon, data for 7,400 tows from 866 trips by 44 different boats. These enhanced logbook data were available for all but 9 of the observed trips, but 10 boats failed to report discards in their logbooks when there was an observer on board.

Preliminary screening and data exploration identified certain aspects of the data that, if ignored, could lead to incorrect interpretations. For example, notes associated with the observer records indicated instances where the observers' discards were "visually estimated"; in many cases the amounts record by the observer were identical to the data from the corresponding logbook, thus grossly overstating the accuracy of the logbook's discard information. Also, the observer notes sometimes indicated that the discard information for specific tow sequences on a trip represented combinations of tows whereby the discards reported for the last tow of the sequence included the discards from the earlier tow(s), which reported no discards. In preparing the data for analysis we removed these false zeroes from the observer data and combined the logbook data from these tow sequences so that we could correctly match the observer data with the logbook data. A final issue regarding the observer data was the presence of large numbers of data records where the observer reported that "unidentified fish" were discarded. In preparing the data for analysis we included a flag variable to identify observed tows that had discards of unidentified fish.

DATA ANALYSIS METHODS

The at-sea observers on the EDCP project collected discard data for a wide range of groundfish species, many more than we could reasonably evaluate in our analyses. We limited our detailed statistical analyses to the following species (or groups of species): "All Fish", Dover sole, sablefish, longspine and shortspine thornyheads, English sole, rex sole, petrale sole, sanddab, all *Sebastes*, canary rockfish, Pacific ocean perch, widow rockfish, yellowtail rockfish, lingcod, and Pacific hake. To facilitate data handling we analyzed the species in groups: deepwater complex (Dover sole, sablefish, and longspine and shortspine thornyheads); flatfish (English sole, rex sole, petrale sole, and sanddab), rockfish (all Sebastes, canary rockfish, Pacific ocean perch, widow rockfish, and yellowtail rockfish), and other fish (lingcod and Pacific hake). We configured the statistical models to include a *Species* factor that allowed us to maintain separate parameter estimates for individual species while analyzing the species collectively.

Evaluating the Accuracy of the Logbook Discard Data

For measuring the accuracy of the discard data in the logbooks we matched the tow-by-tow logbook discard data with the corresponding observer discard data. We then examined two aspects of these combined data: the proportion of tows for which an observed discard of a given species (or species group) was also reported in the corresponding logbook,

$$\%\text{Agreement} = \frac{\text{No. Logbook Tows with Discard of Species X}}{\text{No. Observed Tows with Discard of Species X}} \times 100\% \quad , \tag{1}$$

and the ratio of the amount of discard reported in the logbook over the amount observed,

$$\text{Lbk/Obs Ratio} = \frac{\text{Logbook Discard of Species X (lbs)}}{\text{Observed Discard of Species X (lbs)}} \quad . \tag{2}$$

This method of evaluation assumes that the observer data are correct, but in many cases (e.g., tows with discards of unidentified fish or discards that were "visually estimated") this assumption is not entirely valid.

The %Agreement proportions were calculated for each species on a trip-by-trip basis for all trips having matched logbook and observer data. The Lbk/Obs Ratios were calculated for each species on a tow-by-tow basis for all tows with matched logbook and observer data for which both the logbook and the observer reported some discards.

The %Agreement proportions were formally analyzed using logistic regression methods as implemented in the GLIM Release 4 statistical software (Francis et al. 1993). The logistic regression model can be written

$$\log_e\left(\frac{\%\text{Agreement}}{100\% - \%\text{Agreement}}\right) = \beta_1 \cdot \text{Factor}_1 + \beta_2 \cdot \text{Factor}_2 + \text{K} \tag{3}$$

Logistic regression is an accepted method for the analysis of proportions and other forms of binomial data (Cox and Snell 1989). The Lbk/Obs Ratios were analyzed using the following regression model,

$$\text{Logbook Discard} = (\text{Log/Obs Ratio}) \cdot (\text{Observed Discard}) \cdot \text{Factor}_1 \cdot \text{Factor}_2 \cdot \text{L} \tag{4}$$

The observed Logbook Discards were treated as normally distributed random variables, as in standard regression or analysis of variance.

To assess the statistical significance of different variables and factors that might influence the dependent variables (%Agreement and Lbk/Obs Ratio) we conducted forward-stepwise analyses (Draper and Smith 1966) that examined the relative improvement in fit that resulted from adding explanatory variables to the statistical model. In GLIM the so-called "deviance" statistic, measures how well a statistical model fits the observed data. If the model is correctly specified (i.e., it has the correct variables in the correct formulation), then the deviance is approximately a chi-square random variable; changes in the deviance can be used in an F ratio to evaluate the change in goodness of fit (McCullagh and Nelder 1983),

$$F = \frac{(\Delta \text{ Deviance}) / (\Delta \text{ Degrees of Freedom})}{(\text{Deviance}) / (\text{Degrees of Freedom})} , \tag{5}$$

where the deviance and degrees of freedom in the denominator are from the more complete model. The F ratio can be compared to the corresponding theoretical F distribution to evaluate the statistical significance of the change.

For the %Agreement observations we fit a series of three logistic models to each species. The first model had a single parameter representing the overall proportion agreement, the second had a separate parameter for each boat, and the third had a parameter that allowed %Agreement to vary with the size of the observed discard. For the Lbk/Obs ratios we fit a model with a single overall ratio, another with a separate ratio for each boat, and a third with a separate ratio for each trip. We examined two additional models: one to evaluate the influence of unidentified fish discards (*Ufish*) and the other to evaluate the influence of questionable data (*Qtow*). The *Ufish* variable for a tow was set to one if the unidentified fish discards were 10% or more of all the fish discards for that tow; otherwise it was set to zero. The *Qtow* variable for a tow was set to one if the logbook discard was exactly the same as the observer discard or if the observer discard amount was evenly divisible by 100 (e.g., exactly 400 rather than 402, or exactly 10,000 rather than 10,013).

Estimating the Discard Rates

Because the observers did not weigh the catch retained from each tow, the observer data did not provide any direct measurement of discard rates at the level of individual tows. For our analysis of the observer data we derived discard rates for each groundfish species on a trip-by-trip basis using the ratio

$$\text{Discard Rate} = \frac{\text{Amount Discarded}}{\text{Amount Discarded} + \text{Amount Landed}} . \tag{6}$$

This discard rate measures the fraction of the catch that was discarded (as opposed to the amount of fish discarded per hour of fishing or per trip). We calculated similar discard rates on a trip-by-trip basis from the logbook data. We excluded trips with incomplete discard data, ones with unobserved tows or where the logbook had tows with blank (as opposed to zero) discards. We did not attempt to explore discard rates at the level of individual tows.

We analyzed transformed discard rates using the following type of regression model,

$$\arcsin\left(\sqrt{\text{Discard Rate}}\right) = \beta_1 \cdot \text{Factor}_1 + \beta_2 \cdot \text{Factor}_2 + \text{K} \tag{7}$$

Prior to the regression analysis we applied to the discard rates the so-called "angular transformation" (shown in the left-hand portion of the equation), which is a standard technique for converting proportions so that the resulting values are more normally distributed (Zar 1974). We did not consider it appropriate to use logistic regression with the discard rate data because the proportions were based on estimated weights rather than counts.

To evaluate the importance of various factors that might influence the discard rates we conducted forward-stepwise analyses that examined the relative improvement in fit that resulted from adding explanatory variables to the statistical model. In our analysis of the observer discard rates we examined the factors *Boat*, *Port*, *Gear* type (shrimp trawl, sole trawl, bottom trawl, bottom trawl with rollers), *Area* (Pacific Marine Fishery Commission statistical area), *Year*, and season (quarter of the year, *Qtr*). Also, we tested the importance of factors that identified large (>10%) discards of unidentified fish (*Ufish*) and tows with questionable data (*Qtow*), as in our analysis of logbook discard accuracy, and we fit models that included continuous variables (as opposed to discrete factors) for the size of the catch (*Lbs*) and the tow time (*Hrs*). In our analysis of the logbook discard rates we considered factors for boat, year, and quarter, plus a factor to identify trips that had an observer on board (*Obs*) and a continuous variable for the size of the catch (*Lbs*).

Evaluating Whether the EDCP Data are Representative

The fishing boats in the EDCP program participated on a voluntary basis. Because they cannot be considered a random sample of the trawl fleet at large, it may be inappropriate to extrapolate the results from the EDCP program to the entire fleet. To evaluate whether the boats and fishing trips covered by the EDCP program were representative of the trawl fishery in general, we compared traits of the trips covered by the EDCP program with the traits of the rest of the groundfish trawl trips that landed their catch in Oregon. We obtained fish ticket files from ODFW for the period covered by the EDCP program (16 Nov. 1995 through 31 Dec. 1999) and tabulated on a trip-by-trip basis the total fish landings and the proportions landed by species. The tabulations included the following 21 species or species groups: Pacific hake, English sole, petrale sole, Dover sole, rex sole, sanddab, arrowtooth flounder, small rockfish, large rockfish, Pacific ocean perch, widow rockfish, yellowtail rockfish, canary rockfish, shortspine thornyheads, longspine thornyheads, grenadier, sablefish, lingcod, Pacific mackerel, jack mackerel, and skate). We then applied Principal Components Analysis (PCA) to these landings and species composition data to derive PCA scores, which we treated as summary statistics to characterize each trip. Because the species composition numbers are proportions (restricted to the range 0 to 1) we transformed them using the angular transformation prior to application of PCA. In an auxiliary file we included flag variables to identify trips covered by EDCP observers or EDCP logbooks. We compared the PCA scores of the EDCP trips with the PCA scores of the rest of the trips.

Because we did not have ready access to fish ticket information for trips that landed their catch in California or Washington, our analysis was restricted to trips that landed in Oregon. Also, the fish ticket files that we obtained from ODFW did not include shrimp trawl landings of groundfish, but relatively few of the EDCP trips were aboard boats using shrimp trawls.

RESULTS

The fishing trips that had enhanced logbooks and reported discards landed a total of 11.6 million pounds of fish, caught during 5,134 non-zero tows (Table 1). The logbooks for these trips reported total fish discards of 4.7 million pounds (exclusive of halibut and salmon), most of which was Pacific hake (24.8%), shark (17.8%), or sablefish (10.6%). The rockfish species as a group were 12.8% of the reported discards. The observers reported fish discards (exclusive of halibut and salmon) totaling 2.8 million pounds, from 2,102 tows. The largest category of observed discards was unidentified fish (29.8%). Most of the identified discards were Pacific hake (15.4% of all fish discards), shark (11.3%), and sablefish (7.6%). Rockfish species were 11.9% of the observed discards.

Evaluating the Accuracy of the Logbook Discard Data

More than half of the tows for which observer data were available could not be matched to corresponding logbooks, primarily because nine boats never reported discards when they had an observer on board. However, matched logbook and observer discard data were available from 15 boats for 919 tows during 118 fishing trips (Table 2). Discards of fish were reported in the logbooks or observed on 916 of the tows, and the logbooks reported fish discards for 889 of the 913 tows for which the observer reported fish discards (97.4% agreement). With respect to identifying that individual species had been discarded on a tow, there was in general a fairly poor level of agreement between the logbooks and the observers, except for "high-profile" species such as sablefish (61.4% agreement), canary rockfish (52.2% agreement), and Pacific hake (53.9% agreement). Some species were rarely identified as discards in the logbooks. For example, only 2.7% of the tows with Pacific ocean perch discards and only 2.8% of the tows with English sole discards were correctly identified in the logbooks.

Oddly, the logbooks reported fish discards for three tows for which the observer reported none (Table 2, the column labeled "Lg no Ob"). These may represent reporting errors on the part of the skipper. For a substantial number of tows the logbooks reported discards of unidentified rockfish or unidentified fish that the observer was apparently able to apportion to individual species. However, the moderate numbers of logbook reports of sablefish, Pacific hake, and shark discards that were not seen by the observers are difficult to explain. For our analysis we assumed that the observer records were correct and that the logbooks contained fair numbers of false-positive records of discards.

The ratios of the discards reported in the logbooks over the discards reported by the observers (Table 2) provides another measure of the accuracy of the logbooks (assuming the observer data are completely accurate). When summed over all tows, including those where the logbooks and observers disagreed that there were discards, the total logbook discards for all fish was only 0.79 of the observer discards. For most individual species the discards reported in the logbooks were considerably smaller than the discards reported by the observers. When the discard amounts were limited to those tows where the logbooks and observers agreed that there were discards, the ratios of logbook discards over observer discards were generally much closer to 1.0, as it would be if the logbook discards (and observer discards) were perfectly accurate.

Our formal analysis of the %Agreement between logbooks and observers that discards occurred indicated significant variability ($P < 0.01$) amongst the boats. Even with the "All Fish" discards, for which the overall %Agreement was almost 100%, there was one boat that had 0% agreement and another with only 50% agreement. At the level of individual species there was even more variation in the %Agreement values for the different boats. Except for the "All fish" category, there were significant improvements ($P < 0.005$) in the fits of the logistic regression models when they included a term for the size of the observed discards. Furthermore, the coefficients on the term for the size of the observed discard were positive for all species except sanddabs (where the coefficient was not significantly different from zero), indicating that the %Agreement tended to increase as the observed discards increased. Large discards were more likely to be reported in the logbooks than small ones.

The formal analysis of the Lbk/Obs ratios (for tows that had non-zero discards reported by both the logbooks and observers) also indicated highly significant variation ($P < 0.001$) amongst the boats for the "All fish" category as well as for the individual species, except for those in the flatfish group. Furthermore, there was significant variation ($P < 0.05$) in the Lbk/Obs ratios at the trip-to-trip level for individual boats. When factors were added to identify tows with more than 10% of the observed discards reported as unidentified fish (*Ufsh*), there were very significant improvements ($P < 0.005$) in fit for the "All Fish" category, the Deepwater Complex group, and the Rockfish group. Also, the Lbk/Obs ratios for tows with unidentified fish were in general larger than the ratios for other tows, which is consistent with the idea that the unidentified fish discards included quantities of the focal species, so that the reported discards of the focal species were too small. When factors were added to identify tows with questionable observer data (*Qtow*), there was a significant improvement ($P < 0.001$) in fit for the "All Fish" category but not for the other groups. For the "All Fish" model the Lbk/Obs ratio for the tows without questionable data was 0.67, whereas the ratio for the tows with questionable data was 0.93. Most of the questionable tows were ones having logbook discards that were exactly the same as the observer discards, and many of these also were simple multiples of 100.

Estimating the Discard Rates

Over the course of the entire EDCP program there were 416 trips with complete logbook data (no tows with missing discard information) and there were 205 trips that were fully observed (no tows with missing discard information). We used the discard data from these trips to derive trip-level estimates of discard rate averages and standard deviations (Table 3). In general the discard rates based on the logbooks were smaller than the rates based on the observers by a factor of 0.92. The ratio of the logbook discard rate over the observer discard rate was variable among the different species, ranging from a low of 0.16 for petrale sole to 1.7 for widow rockfish. The discard rates from the logbooks were generally more variable than the rates based on the observer data, with the coefficients of variation from the logbook data being about 1.2 times larger than the coefficients of variation from the observer data.

Our formal analysis of the transformed discard rates derived from the observer data indicated highly significant variation ($P < 0.001$) among the boats for the "All Fish" category and for all of the individual species groups. As measured by the rank of an adjusted R^2 statistic, *Boat* had the greatest explanatory power of all the factors considered. The factors *Port* and *Area* were also important and significant explanatory variables ($P < 0.001$). The factors for trips having tows with unidentified fish (*Ufsh*) and those having tows with questionable data (*Qtow*) were often significant ($P < 0.05$), but had much less explanatory power than the other variables. The variables for the size of the total catch (*Lbs*) and the tow duration (*Hrs*) were also significant but low ranking explanatory variables. We examined interactions between *Boat* and the other factors to evaluate in greater detail the importance of the other factors. This analysis indicated a strong *Gear* effect on the boat-specific discard rates for the "All Fish" category, a strong seasonal effect (*Qtr*) on the rates for the deepwater complex and flatfish species, a strong *Area* effect on the rates for the rockfish species, and a strong *Year* effect on the rates for the other species (lingcod and Pacific hake).

The analysis of the transformed discard rates derived from the logbook data also indicated highly significant ($P < 0.001$) variation among the boats for the "All Fish" category and for all of the individual species groups. Our analysis of interactions between *Boat* and the other factors indicated a strong *Year* effect on the boat-specific discard rates for the "All Fish" category and all the individual species groups except rockfish, for which the seasonal effect (*Qtr*) ranked higher than the *Year* effect. The factor identifying trips with observers on board (*Obs*) was generally significant ($P < 0.05$), either as a main effect or as an interaction with *Boat*, which suggests that skippers and crews may have altered either their discarding practices or discard reporting practices when an observer was present.

Evaluating Whether the EDCP Data are Representative

To facilitate our analysis of fishing trip characteristics and whether those trips covered by the EDCP were representative, we divided the trip-level groundfish trawl landings in Oregon during the study period into two categories: "non-hake" trips that landed less than 50% Pacific hake and "hake" trips. EDCP logbooks or observers covered none of the hake trips because ODFW samplers regularly monitor the shore-based fishery for hake in Oregon for discards and bycatch. The 9,727 non-hake trips accounted for 21% of the overall landings of fish in Oregon and 69% of the groundfish trips.

Principal Components Analysis (PCA) was applied to the trip-level data on overall landings and species composition (percent by weight) to derive a small number of summary statistics for each trip. The PCA for the data from the non-hake trips was moderately successful at simplifying the data, with the first three PCA axes accounting for 13.9%, 12.2%, and 8.2% of the variability in the data. Ideally, the first two or three principal components should account for 50% or more of the variability in the data being analyzed, but for these data the first three components only "explained" 34% of the variability.

We calculated simple t-statistics to formally compare the PCA scores from the trips that were part of the EDCP with those that were not. For the non-hake trips we found statistically significant differences ($P < 0.001$) between the PCA scores from the trips that had enhanced logbooks (672 trips) versus those that did not for Axes 1 and 2, and between the scores from the trips covered by observers (170 trips) versus those that were not for Axes 2 and 3. These results indicate that the trips covered by the EDCP made landings that had different species compositions than the landings by trips that were not covered under the EDCP. These results provide no support for the presumption that the trips covered by the EDCP were representative of the fleet at large.

DISCUSSION

Collecting information on discards and bycatch is a time-consuming and costly process. However, unless reasonably accurate information is available on fishery removals (landings plus discards), it is very likely that stock assessments will produce estimates of exploitable stock size that are biased, or at least highly uncertain. Logbooks provide a relatively inexpensive mechanism for collecting large quantities of data on discards and bycatch. Our direct comparisons of the logbook discard data with the observer discard data, however, generally indicated that the enhanced logbooks were not very accurate either in terms of their identification of discards or their estimates of the amount discarded. Non-reporting of discards seemed especially to be a problem with unimportant species such as flatfish, which are routinely discarded when they are of unmarketable size. Non-reporting of discards of Pacific ocean perch was also a particular problem, presumably because fishers have been discarding small amounts of this species for so long that they are no longer even aware of the practice. However, given the intensity of debate in recent years over the catch quotas and trip limit regulations for thornyheads, the non-reporting of discards of the two thornyhead species was surprisingly large (62% non-agreement for longspine thornyheads, 70% non-agreement for shortspine thornyheads).

The estimates of discarding derived from the logbook data were not accurate at the level of individual tows, but the discard rates derived from the logbook data by averaging across tows and trips were fairly comparable to those based on the observer data, although they were generally biased low. It should be feasible to develop bias-adjustment factors that could be used to inflate the logbook discard rates so that they more closely resemble the discard rates recorded by the at-sea observers. Extensive collections of discard data from logbooks would greatly increase the sample size and thus could provide much more precise estimates of discard rates. Because the discard rate estimates from the logbook data were generally more variable than the discard rates derived from the observer data, it will take two or three trips with logbook data to achieve the same degree of precision as a single observed trip. Except for Pacific hake (discard rate $\approx$ 100%), the discard rates from both the logbook and observer data were extremely variable, with coefficients of variation ranging from 98% (sanddab) to 791% (petrale sole) for the logbook data, and from 76% (sablefish) to 611% (widow rockfish) for the observer data. Such high levels of variability imply that discard data will be needed from very large numbers of trips to obtain reliable estimates of discard rates.

Large boat-to-boat variations in the data were a dominant feature in the results from our analyses of the accuracy of the logbook discards and the estimates of discard rates derived from the logbook data and the observer data. Data collected from one set of boats could be markedly different from the data collected from a different set of boats, which implies that large numbers of boats will need to be sampled in any program that monitors discards.

If future programs use fishers' logbooks to record discards, the programs should provide the fishers with more training and practice to identify species and estimate discard amounts. In our tow-by-tow comparisons of the logbook data with the observer data it appeared that discrepancies between the two sometimes were the result of differences in species identification, for example, with the skipper reporting discards of miscellaneous rockfish while the observer reported several individual rockfish species. Also, a training program could encourage the fishers to be more aware of discarding so that small discards would not go unnoticed, as apparently occurred with the logbooks in this study. Finally, the training program should help the fishers learn how to estimate discard amounts, especially for species that are not usually landed. With species that are routinely discarded (e.g., dogfish) the fishers never receive feedback to help them learn whether they have correctly estimated the weight of the fish they discarded. With retained marketable species they have an opportunity to learn from their bad estimates, for example, when the processor pays them for 1000 pounds of fish but they thought they caught 2000 pounds.

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Table 1. Summary of landings and discards by species reported in the enhanced logbooks and by the observers.

	------------------- Logbook Data -------------------					------------ Observer Data ------------			
Name	No. Tows	Landings [a]	Discards [a]	%All	Rank	No. Tows	Discards [a]	%All	Rank
All Fish [b]	5134	11597.2	4705.7	100%	1	2102	2869.4	100%	1
Dover Sole	3276	2573.6	229.5	4.9%	8	798	84.3	2.9%	11
Sablefish	3311	922.9	500.1	10.6%	5	969	219.5	7.6%	6
Longspine Thornyheads	1717	1114.8	76.5	1.6%	16	424	50.5	1.8%	13
Shortspine Thornyheads	2440	332.0	89.0	1.9%	14	583	45.5	1.6%	14
Thornyhead Unidentified	344	0.0	38.0	0.8%	20	2	0.4	0.0%	32
Arrowtooth Flounder	2159	869.7	108.1	2.3%	11	592	54.6	1.9%	12
Canary Rockfish	1743	233.5	27.7	0.6%	23	53	14.3	0.5%	20
Pacific Ocean Perch	582	183.0	9.9	0.2%	28	148	13.9	0.5%	21
Widow Rockfish	1297	1594.4	79.7	1.7%	15	52	9.7	0.3%	22
Yellowtail Rockfish	1373	696.8	189.9	4.0%	10	172	131.0	4.6%	9
All Sebastes	3774	1687.7	603.0	12.8%	4	1062	341.7	11.9%	4
Bocaccio Rockfish	73	14.1	7.3	0.2%	30			0.0%	40
Black Rockfish	14	0.8	0.0	0.0%	42			0.0%	40
Large Rockfish	2065	293.6	17.3	0.4%	27	73	0.6	0.0%	31
Small Rockfish	2108	378.0	337.5	7.2%	6	844	170.0	5.9%	8
Other Rockfish	249	71.0	23.3	0.5%	24	180	25.7	0.9%	16
English Sole	2338	223.1	18.2	0.4%	26	359	6.8	0.2%	23
Petrale Sole	2353	530.9	2.7	0.1%	32	227	4.4	0.2%	25
Rex Sole	2542	175.2	33.9	0.7%	21	844	39.8	1.4%	15
Pacific Sanddab	268	100.1	50.5	1.1%	17	235	25.4	0.9%	17
Butter Sole	58	0.2	0.2	0.0%	35	2	0.0	0.0%	38
Curlfin Sole	14	0.3	0.0	0.0%	42	4	0.0	0.0%	36
Rock Sole	96	1.1	0.0	0.0%	41	3	0.0	0.0%	37
Sand Sole	105	13.2	0.2	0.0%	36	14	0.1	0.0%	34
Starry Flounder	67	5.9	0.1	0.0%	40	1	0.0	0.0%	39
Other Flatfish	55	0.6	7.3	0.2%	29	689	17.1	0.6%	19
Lingcod	1898	367.5	47.2	1.0%	18	277	21.5	0.8%	18
Pacific Hake	2020	12.2	1168.4	24.8%	2	1180	441.3	15.4%	3
Pacific Cod	780	53.4	0.1	0.0%	37	101	1.8	0.1%	27
Shark unidentified	947	31.2	839.5	17.8%	3	1104	324.7	11.3%	5
Skate unidentified	2923	386.4	206.0	4.4%	9	1108	116.7	4.1%	10
Chub Mackerel (Pacific)	48	2.2	0.4	0.0%	33	83	1.7	0.1%	28
Jack Mackerel	35	2.6	0.4	0.0%	34	85	2.9	0.1%	26
Nearshore Mixed Fish	33	0.0	45.3	1.0%	19			0.0%	40
Octopus Unspecified	301	1.8	0.1	0.0%	39	118	1.3	0.0%	30
Squid Unspecified	213	18.7	6.3	0.1%	31	257	6.3	0.2%	24
Sturgeon	7	0.2	0.1	0.0%	38			0.0%	40
Miscellaneous Fish	1624	274.6	299.8	6.4%	7	1403	180.0	6.3%	7
Flatfish Unidentified	200	0.0	21.5	0.5%	25	20	0.3	0.0%	33
Rockfish Unidentified	399	117.7	106.2	2.3%	12	39	1.6	0.1%	29
Flatfish Unidentified	407	0.0	89.1	1.9%	13	317	854.9	29.8%	2
Mackerel Unidentified	44	0.0	28.6	0.6%	22	10	0.0	0.0%	35

[a] Thousands of pounds.
[b] Excluding Pacific halibut and salmon.

Table 2. Accuracy of logbook discard records based on matched logbook and observer tows. The columns labeled "Discards (Lg>0 & Ob>0)" are the discard amounts for those matched tows where both the logbook and the observer reported non-zero discards for the given species.

			-------- Tows w Discard --------				----- Discards (all tows) -----			Discards (Lg>0 & Ob>0)		
Species	N Trips	N Tows	Lg no Ob	Lg+Ob	Obs	%Agree	Log [a]	Obs [a]	ratio	Log [a]	Obs [a]	ratio
All Fish	118	919	3	889	913	97.4%	906.55	1151.91	0.79	906.48	1141.71	0.79
Dover sole	112	644	20	66	398	16.6%	24.37	29.75	0.82	19.48	20.53	0.95
Sablefish	112	657	39	310	505	61.4%	81.90	110.39	0.74	73.84	97.77	0.76
Longspine th	89	332	13	96	253	37.9%	15.98	24.46	0.65	14.41	13.73	1.05
Shortspine th	103	511	27	94	313	30.0%	17.39	26.19	0.66	14.25	11.91	1.20
Thornyheads	29	81	81	0	0		10.29	0.00				
Canary rk	56	111	5	12	23	52.2%	14.95	8.70	1.72	8.05	8.47	0.95
Pac oc perch	52	146	1	2	75	2.7%	2.30	2.96	0.78	2.00	1.84	1.09
Widow rk	58	147	2	6	25	24.0%	6.41	9.08	0.71	5.33	3.82	1.40
Yellowtail rk	56	193	7	22	52	42.3%	28.30	38.25	0.74	26.65	32.41	0.82
All Sebastes	109	607	32	188	481	39.1%	156.58	157.80	0.99	114.46	126.14	0.91
English sole	83	198	1	4	142	2.8%	0.17	2.05	0.08	0.16	0.10	1.62
Petrale sole	93	230	4	3	97	3.1%	0.25	1.20	0.21	0.01	0.05	0.28
Rex sole	96	441	7	42	406	10.3%	9.26	28.52	0.32	7.17	6.41	1.12
Sanddab	35	97	2	10	94	10.6%	9.98	17.97	0.56	8.38	13.97	0.60
Lingcod	82	231	3	16	101	15.8%	1.66	3.52	0.47	1.49	2.05	0.73
Pac hake	108	614	41	309	573	53.9%	180.19	182.83	0.99	129.44	151.29	0.86
Shark	109	541	33	104	508	20.5%	140.23	85.03	1.65	54.45	70.75	0.77
Skate	113	625	31	177	558	31.7%	22.41	46.96	0.48	19.00	29.17	0.65
UnID flatfish	20	54	43	4	11	36.4%	8.72	0.07	121.28	0.53	0.04	12.59
UnID rockfish	30	100	100	0	0		44.35	0.00				
UnID fish	82	306	209	31	97	32.0%	56.62	278.53	0.20	14.53	49.43	0.29

[a] Thousands of pounds.

Table 3. Discard rates from trips with logbooks versus trips with observers. These tabulations do not include trips with tows that were unobserved or for which logbook discards were missing.

Species	No. Trips	Landings [a]	Logbook Discards [a]	Discard Rate	St. Dev.	Coef. Var.
Complete logbook trips						
All Fish	416	6997.02	2551.50	0.2672	0.1914	0.7162
Dover sole	385	1468.35	98.49	0.0629	0.1583	2.5170
Sablefish	383	562.79	282.96	0.3346	0.3271	0.9774
Longspine th	284	714.44	51.51	0.0673	0.1016	1.5091
Shortspine th	327	201.55	55.24	0.2151	0.2962	1.3770
English sole	297	156.66	12.63	0.0746	0.0953	1.2769
Petrale sole	320	349.86	0.92	0.0026	0.0206	7.9077
Sanddab	48	53.13	45.07	0.4589	0.4528	0.9867
Lingcod	274	174.38	19.02	0.0983	0.2417	2.4589
Pac Hake	303	2.33	657.29	0.9965	0.0503	0.0505
Sebastes	368	905.87	318.73	0.2603	0.2855	1.0967
Canary rf	202	125.57	16.05	0.1133	0.2489	2.1970
Pac oc perch	85	109.32	7.58	0.0648	0.2133	3.2923
Widow rf	186	979.45	39.26	0.0385	0.1081	2.8088
Yellowtail rf	193	396.34	100.87	0.2029	0.3467	1.7086
Fully observed trips						
All Fish	205	4091.86	2568.50	0.3856	0.1841	0.4775
Dover sole	190	740.85	77.16	0.0943	0.2131	2.2593
Sablefish	192	283.28	203.25	0.4178	0.3183	0.7619
Longspine th	139	333.09	47.07	0.1238	0.1535	1.2393
Shortspine th	180	98.60	43.40	0.3056	0.3327	1.0886
English sole	152	69.64	6.50	0.0853	0.1240	1.4530
Petrale sole	167	182.81	3.09	0.0166	0.0568	3.4163
Sanddab	68	22.25	21.06	0.4863	0.4483	0.9219
Lingcod	154	162.32	21.34	0.1162	0.2640	2.2716
Pac Hake	185	0.00	399.13	1.0000	0.0000	0.0000
Sebastes	193	871.80	325.22	0.2717	0.2621	0.9645
Canary rf	111	95.68	14.33	0.1303	0.2787	2.1392
Pac oc perch	93	112.41	12.03	0.0967	0.2030	2.0998
Widow rf	111	416.16	9.68	0.0227	0.1389	6.1097
Yellowtail rf	120	447.39	126.29	0.2201	0.3428	1.5570

[a] Thousands of pounds.